

# DISCOVERY

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# Development of improved batch process abrasive cassava peeling machine

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## ABSTRACT

The need to mitigate the low output, drudgery, high labour costs and losses associated with manual peeling called for the design of the machine to improve the agricultural yield of the crop. An improved abrasive cassava peeling machine was developed and tested. The performance evaluation of the cassava peeling machine was evaluated based on given sample size and cassava tuber peeling time in the peeling chamber. The performance parameters determined include the machine peeling efficiency, peeling capacity/throughput and flesh loss. The machine gave an average peeling efficiency of 90.97% and throughput of 382 tubers/hr of cassava. It was observed that low speed favours efficient operation of the machine. From the results obtained, this project is efficient and effective.

**Keywords:** Batch Process, Abrasion, Cassava Peeling Machine, Peeling Capacity, Development

## 1. INTRODUCTION

Cassava (*Manihot Esculenta Crantz*) was introduced by the Portuguese during the 16th and 17th centuries from Brazil to the tropical regions of Africa, the East and Caribbean islands. Cassava is currently one of the most significant and frequently grown crops in sub-Saharan Africa. With an annual output of about 34 million tons of tuberous roots, Nigeria is now the greatest cassava grower in the world (Ohwovoriole et al., 2018). The crop is usually divided into two categories: Sweet cassava and bitter cassava (*manihotutilissima* or *manihot palmate*), respectively. Cassava was previously grown primarily for human consumption in most homes in sub-Saharan Africa, but it has lately gained significant industrial significance on a national and worldwide level. In order to minimize the harmful cyanogenic glycoside, which is more concentrated in the peel and is inedible, the crop peel, also known as the inedible portion, must be removed and further processed. Cassava is now among the key crops that are necessary for both promoting exports and local consumption. In addition to being utilized as food for humans, cassava is also used to make alcohol (Akintunde et al., 2017). The market for cassava chips and pellets is rising worldwide, especially in China and Brazil. So, cassava may be considered a crop with several uses for humans and animals.

Cassava tubers must be processed right once after being harvested since, due to their high-water content, they start to degrade within 72 hours (Kolawole et al.,

2007). The following steps—peeling, washing, grating, pulverizing, fermenting, dewatering/pressing, frying and occasionally cooking—must all be completed in order to transform cassava into forms that may be used (Nwadinobi et al., 2019). Peeling is the first and most crucial stage in the processing of cassava among all of these procedures. In the past, peeling is done using knives and matchets. This method, which requires a typical person to peel 20 to 25 kg of roots each day, is laborious, time-consuming and unsuitable for processing on a big scale. In addition to being laborious and slow, hand peeling results in a significant loss of edible flesh. This technique has been shown to result in a 30% loss of useable meat (Olukunle et al., 2010). Even though mechanical peeling equipment have been invented, they have not all been adopted, as they are expensive and have not been shown to fully resolve farmers' peeling challenges. Therefore, the majority of farmers are reluctant to use this equipment.

Despite the availability of various cassava peeling machines in the market, there are still limitations and challenges faced by users in terms of efficiency, cost-effectiveness, durability and safety. The existing cassava peelers have low peeling capacity, high power consumption and often cause damage to the cassava tubers during peeling, leading to reduced yield and quality of the processed products. Moreover, they are often expensive, difficult to maintain and pose safety risks to operators due to their manual or semi-automatic design. Therefore, there is a need to develop an improved cassava peeling machine that addresses these limitations and provides a more efficient, cost-effective, durable and safe peeling solution for farmers and processors. The new cassava peeler has high peeling capacity, low power consumption, gentle peeling action and easy maintenance. It is also affordable, user-friendly and complies with safety standards to minimize accidents and injuries during operation.

## 2. MATERIALS AND METHOD

In fabricating the cassava peeling machine, the design based on the feasibility study was carried out with the following considerations. The materials for construction of the machine were chosen based on their availability, properties, machinability and economic considerations.

### Design Consideration and machine components

In order to achieve high efficiency and reliability, the machine was designed based on the following considerations:

Required capacity of the machine; It should have high capacity and be able to reduce labour requirements compared to manual peeling.

Portability and ease of operation of the machine; It should be simple in design and able to peel different varieties, shapes and sizes of cassava tubers.

The material used should be readily available materials most of which should be locally sourced; fabrication materials should not contaminate the peeled cassava tubers but should possess ability to withstand corrosion, wear and tear.

To preserve the quality of food, affordability, availability, strength of the materials of construction, the physical and chemical properties of cassava tubers to be peeled were given due consideration (e.g., specific weight, density, size, impact, tensile and compressive strength).

The overall cost of the machine; It should be cheap and within the purchasing capacity of local farmers.

The cassava peeling machine has the following as its components:

The power transmission system: This comprises of an electric motor, pulleys, v-belt, bearings and the shaft.

The peeling chamber: This comprises of the abrasive peeling cylinder and its support attachments. Figure 1 shows the abrasive peeling machine outlook.

### Working principle of a cassava peeling machine

The outer peel of the cassava root is normally removed using mechanical abrasion. The cassava root is fed into the device, where the peel is scraped off by agitating it against the rough surface of the peeler. To peel the cassava, the machine combines mechanical and water abrasion. The water removes the dirt while simultaneously softening the peel. When cassava is introduced into the peeling chamber, the rotating peeling drum, continuously scrubs the peel away from the cassava tubers. At the same time, water is continuously sprayed and the dirt washed from the cassava is washed away together with the peelings through the clearances provided within the peeling drum. The clean peeled cassava is discharged through the outlet provided. The peeled cassava can thereafter be collected ready for further processing. The exploded views and components of the designed cassava peeling machine are labeled (Figure 2).

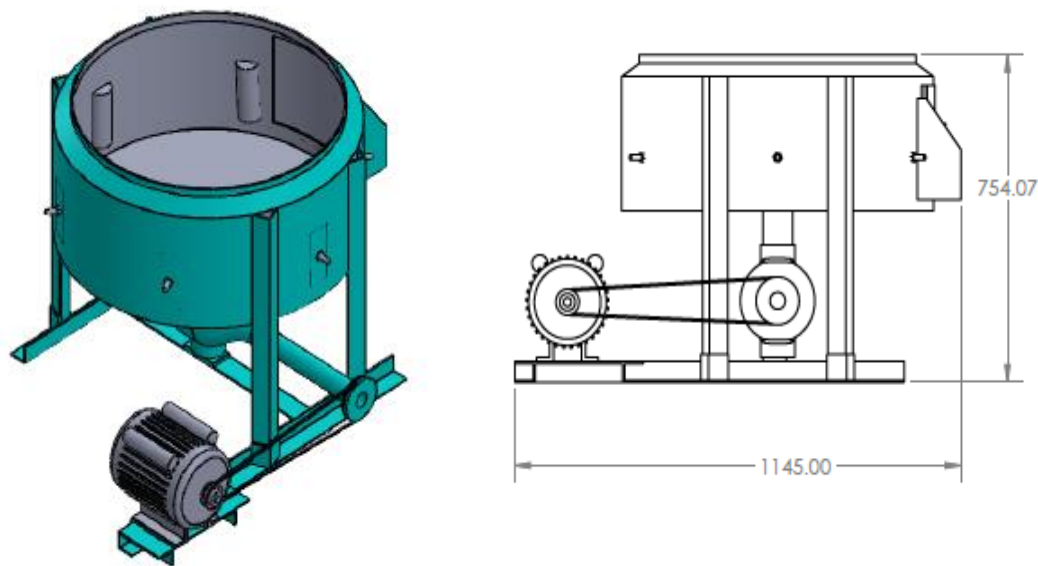
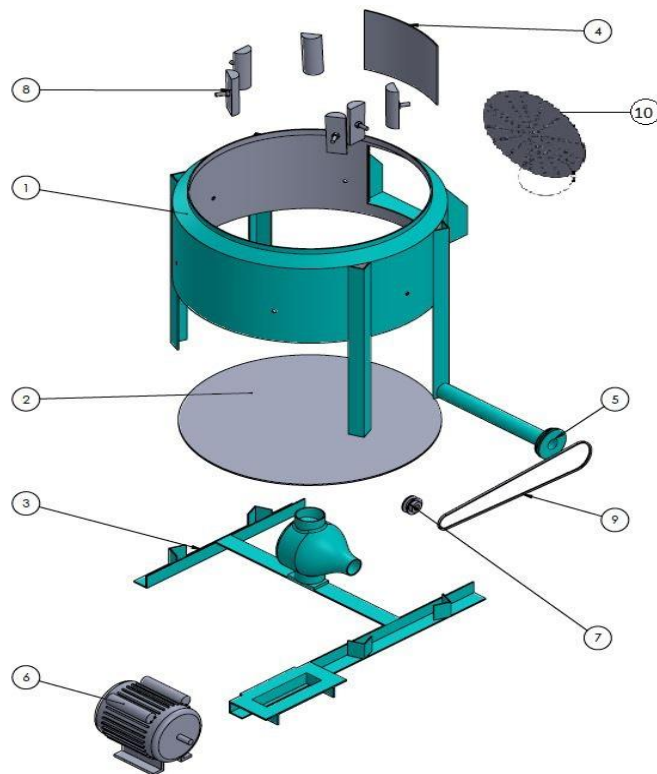


Figure 1 Peeling machine outlook



ITEM NO.	PART NUMBER	QTY.
1	washing chamber	1
2	Rotor	1
3	Base frame	1
4	Discharge Door	1
5	Drive Shaft	1
6	Electric Motor	1
7	Small Pulley	1
8	Bomb	6
9	Drive Belt	1
10	Abrasive material	1

Figure 2 Designed component of the cassava peeling machine

### Design Calculation

#### Power required to Peel Cassava

The abrasive drum peeling concept was selected for the design of the peeler.

$$\text{Weight of the peeling drum} = \rho g \times \pi D t (L + 2). \quad (1)$$

$$\text{Mass of the peeling drum, } m = \rho \times \pi D t (L + 2). \quad (2)$$

Where:  $\rho$  = material density for the peeling drum. The peeling drum was made from density stainless steel material with a density of  $7.8 \times 10^3 \text{ kg/m}^3$  (Khurmi and Gupta, 2015);  $D$  = diameter for the peeling drum = 400mm;  $t$  = thickness for the peeling drum = 3mm;  $L$  = length for the peeling drum = 1000mm.

$$\text{Therefore, } m = 7.8 \times 10^3 \times 3.142 \times 400 \times 3 \times (1000 + 2) = 29.5 \text{ kg}$$

Weight of peeling drum,  $w = mg$ , where  $g$  is acceleration due to gravity

$$w = 29.5 \times 9.81 = 289.4 \text{ N}$$

Power required to peel cassava is the power that turns the shaft

$$P = m \left( \frac{2\pi r N}{60} \right)^2 \quad (3)$$

$r$  = radius of the peeling drum = 200mm; The speed of the shaft,  $N = 420 \text{ rpm}$  was selected basing on the speed of an auger shaft used in some peeler machines (Oluwole and Adio, 2020; Akintunde et al., 2020).

$$P = 29.5 \left( \frac{2 \times 33.14 \times 0.2 \times 420}{60} \right)^2 = 2280.166 \text{ W} = 2.28 \text{ KW (3 Horsepower)}$$

The power requirement for the cassava peeler is  $P = (2280.166/746) = 3 \text{ HP}$ .

The force  $F$  required for peeling is equal to the force due to the centrifugal action of the peeling drum.

$$\text{Peeling force, } F = \frac{\rho V r \times 4\pi^2 N^2}{3600} \quad (4)$$

$$F = \frac{7.8 \times 10^3 \times 3.78 \times 10^{-3} \times 4 \times 3.14 \times 2^2 \times 420^2}{3600} = 32.04 \text{ N}$$

The torque transmitted by the shaft,  $T = F \times r = 32.04 \times 0.2 = 6.408 \text{ Nm}$

### Pulley selection

The driving pulley was mounted on the shaft of the engine and the driven pulley mounted on the machine shaft. Due to its good strength, availability and cost, cast iron pulleys were selected.

The maximum speed of driver pulley (on the engine),  $N_1 = 1400 \text{ rpm}$

Diameter of driver pulley,  $D_1 = 75 \text{ mm}$ ,

The maximum speed of driven pulley,  $N_2 = 420 \text{ rpm}$

$$\text{The diameter of driven pulley, } D_2 = \frac{N_1 D_1}{N_2} \quad (5)$$

$$D_2 = \frac{75 \times 1400}{420} = 250 \text{ mm}$$

### V-Belt design

A belt provides a convenient means of transferring power from one shaft to another. Belts are frequently necessary to reduce the higher rotational speeds of electric engines to lower values required by mechanical equipment.

The length of the belt is given by:

$$L = \frac{\pi}{2} (d_2 + d_1) + 2x + \frac{(d_2 - d_1)^2}{4x} \quad (6)$$

Where:  $L$  = length of belt;  $d_2$  = diameter of the driven pulley;  $d_1$  = diameter of the driving pulley;  $x$  = distance between the pulleys.

### Shaft design

The minimum shaft diameter needed to avoid failure of the shaft is calculated thus:

#### Torque on the Shaft

$$T_A = \frac{60P}{2\pi N_A} \quad (7)$$

Where  $P$  is the power delivered to the pulley by the motor, and  $N_A$  is the speed of the rotation of the pulley, which can be determined from the speed ratio of the shaft and the motor as thus:

$$\frac{N_A}{N_M} = \frac{d}{D} \quad (8)$$

$$N_A = \frac{N_M d}{D} \quad (9)$$

Where:  $N_M$  is the motor speed,  $d$  is the motor pulley diameter and  $D$  is the shaft pulley diameter. The torque  $T_C$  acting at C must be equal to that at A for equilibrium of the shaft. Hence,

$$T_C = \frac{60P}{2\pi N_A} \quad (10)$$

Where,  $P$  is the power delivered to the pulley by the motor and  $N_A$  is the speed of the rotation of the pulley, which can be determined from the speed ratio of the shaft and the motor

### The transmission shaft

The machine shaft is made of mild steel. The maximum permissible shear stress is 42MPa for transmission shafts with allowance for keyways (Khurmi and Gupta, 2015). The assumption is that the load is gradually applied along the shaft; thus, the combined shock and fatigue factor applied to bending moment,  $K_b = 1.5$  and combined shock and fatigue factor applied to torsional moment,  $K_t = 1.0$ . Since the pulley is keyed to the shaft,  $\tau = 42\text{MPa} = 42\text{ N/mm}^2$

Since the shaft is to experience varying loads, a factor of safety 1.5 was selected for design (Khurmi and Gupta, 2015).

Design shear stress,  $\delta\tau_y = \frac{42}{1.5} = 28\text{N/mm}^2$

From the solid works drawings; the properties of the pulleys were obtained.

For the 75mm pulley: Mass = 486.27g; Volume = 67537.07mm<sup>3</sup>; Surface area = 27939.80 mm<sup>2</sup>; Density,  $\rho = 0.01\text{g/mm}^3$ .

For the 250mm pulley: Mass = 7398.74g; Volume = 1027603.26mm<sup>3</sup>; Surface area = 166964.45 mm<sup>2</sup>; Density,  $\rho = 0.01\text{g/mm}^3$ .

Weight of the pulley (WP) = mass x acceleration due to gravity

Total weight of the pulley =  $(486.27 + 7398.7) \times 9.81 \times 10^{-3} = 77.35\text{ N}$ .

### Design of the volumetric capacity of the machine

According to the previous study volumetric capacity of the machine is given as:

$$Q_{vc} = \frac{Q_e}{\rho} \quad (11)$$

Where:  $Q_{vc}$  = volumetric capacity;  $Q_e$  = the theoretical capacity of the peeler;  $\rho$  = the density of cassava tubers in kg/m<sup>3</sup>.



**Figure 3** Fabricated Cassava Tuber Peeler

## 3. RESULT AND DISCUSSION

The machine having completed, in terms of design and fabrication, was tested to verify if the efficiency of peeling is satisfactory. The peeling machine was tested with approximately linear cassava. With continuous rotation of the handle, the tuber portion that comes in contact with peeling drum was rapidly bruised off. The Efficiency of peeling of the machine was estimated using the ratio of Thickness of tuber peeled by machine ( $t_a$ ) to the ideal thickness to be peeled by machine ( $t_i$ ). Thus,

$$\text{Efficiency} = \frac{t_a}{t_i} \times 100 \quad (12)$$

From 3 sample sets, the efficiency was estimated (Table 1).

**Table 1** Result of Cassava Sample Peeling Test operation

Experimental runs	Diameter of tuber before peeling (mm)	Diameter of tuber after peeling (mm)	Thickness of peel by machine (mm)	Ideal thickness to be peeled (mm)	Efficiency (%)
1	52.37	50.90	1.47	2.00	73.5
2	55.61	54.10	1.51	2.00	75.5

3	58.41	56.86	1.55	2.00	77.5
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Table 1 shows the performance evaluation of the cassava peeling machine which was carried out with 3Hp (1400rpm) electric motor. The result indicates that three (3) runs of experiment were conducted. The efficiencies calculated were 73.5%, 75.5% and 77.5% respectively. The average result of the three runs was calculated and obtained as 75.5%. Further, Table 2 shows the throughput and machine efficiency of the machine in relation to sample size and peeling time.

**Table 2** Cassava peeling capacity

Sample Size	Peeling Time (min)	Number of fully peeled tubers	Number of partially peeled tubers	Number of unpeeled tubers	Machine Throughput (tubers/hr)	Machine Efficiency (%)
70	10	65	3	2	390	92.9
70	10	62	5	2	372	88.6
70	10	64	3	3	384	91.4
Average	10	63.67	3.67	2.3	382	90.97

In Table 2, three runs of machine throughput test were carried out. In the test, 70 cassava tubers were peeled with the peeling machine. Each sample was poured on the peeling drum and the motor was energized and the peeling operation takes place for 10min. at the end of each run, the relevant readings are taken. The following result was obtained within the operational time, as 64 tubers were peeled efficiently, 4 tubers were peeled partially while 3 tubers could not be peeled. Thus, in 60mins (1hr), 382 cassava tubers were fully peeled. The machine gave an average peeling efficiency of 90.97% and throughput of 382 tubers/hr of cassava.

#### 4. CONCLUSION

An improved abrasive cassava peeling machine was developed and tested. The performance evaluation of the cassava peeling machine was evaluated based on given sample size and cassava tuber peeling time in the peeling chamber. The performance parameters determined include the machine peeling efficiency, peeling capacity/throughput and flesh loss. The machine gave an average peeling efficiency of 90.97% and throughput of 382 tubers/hr of cassava. It was observed that low speed favours efficient operation of the machine. From the results obtained, this project is efficient and effective. Hence it can yield benefits to the medium or small-scale cassava processing entrepreneur. This machine has no environment threats, in addition to the availability of fabrication materials within the locality.

#### Informed consent

Not applicable.

#### Ethical approval

Not applicable.

#### Conflicts of interests

The authors declare that there are no conflicts of interests.

#### Funding

The study has not received any external funding.

#### Data and materials availability

All data associated with this study are present in the paper.

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